**MEMORANDUM**

**To:** Ron Stamm **Date:** May 8, 2013

**From:** Tunnel Advisory Panel and PB Team

**Copies:** DCC

**Subject:** **Review of Leighton Consulting, Inc. Report (December 2012) and Implications for Century City Station**

## Introduction and Summary of Review

The Metro team has reviewed the recent Leighton Consulting, Inc. (LCI) report dated December 28, 2012[1] and the California Geological Survey (CGS) letter with same subject dated March 15, 2013[2]. The LCI report contains results of recent boreholes and a trench that were conducted on a transect along the northwest property line of the Beverly Hills High School (BHHS) campus at the request of CGS.

In the BHHS trench and bore holes LCI identified a major fault that is aligned with and to the east of the fault zone south of Santa Monica Boulevard previously mapped by Metro. As discussed below, LCI's identification of this eastern continuation of the southernmost strand of the Santa Monica fault system helps to clarify the locations and extents of the numerous faults in the zone of structural complexity at the complex intersection of the Santa Monica and northern Newport-Inglewood fault systems in the Century City-Beverly Hills area.

The LCI report concludes that there are no active faults on the northern BHHS campus, which encompasses a small portion of the Newport-Inglewood Fault Zone (NIFZ) mapped by Metro. The letter from CGS concurs with that conclusion. However, the LCI observations and investigations do not extend beyond 100 feet north of the northern portion of the BHHS campus, and the LCI report and CGS letter do not address the presence of faulting at the former proposed station sites along Santa Monica Boulevard.

This memorandum summarizes Metro's conclusions considering the new fault data from LCI and previous studies. In summary, after review of the LCI report and data, the Metro team reconfirms its recommendation that the Century City station should not be sited on Santa Monica Boulevard.

## Metro Station Design Approaches and Criteria

Seismic design criteria for buildings in the United States and for tunnels, stations and bridges associated with Metro Rail Systems use the concept of design for life safety and no structural collapse for a maximum design earthquake (MDE). In addition, to avoid significant disruption to transit services, Metro design criteria require that damage be repairable after an MDE event.

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[1] Leighton Consulting, Inc., *Second Response to California Geological Survey Review Comments, Fault Rupture Hazard Review, Beverly Hills High School, 241 South Moreno Drive, Beverly Hills, CA*, dated December 28, 2012, Project No. 603314-008.

[2] California Geological Survey, *Second Fault Rupture Hazard Review, Beverly Hills High School, 241 S. Moreno Drive, Beverly Hills, CA*, March 15, 2013, CGS Application No. 03-CGS0960.

For MDE events on the Santa Monica or Newport Inglewood fault zones, fault displacements could be of the order of several feet. Design of Metro's underground stations (complex two-story structures up to 1,000 feet long, including systems and ventilation equipment) to withstand such displacements without significant damage and potential loss of life, would be impractical and without precedent. Expected damage levels would require a complete rebuild of the stations, with a construction time frame of years.

In addition to considerations of public safety and repairability associated with siting passenger stations within a zone of active faulting, both Santa Monica Boulevard stations would require a longer length of tunnel to be within and sub-parallel to the Santa Monica Fault Zone (SMFZ), subjecting the public and transit facility to greater risk in a seismic event.

**CGS Designation of SMFZ, NIFZ, and HFZ as Active Faults**

The 2005 Digital Database of Quaternary and Younger Faults from the Fault Activity Map of California by the California Geological Survey (CGS) identifies the Santa Monica Fault Zone, the Newport–Inglewood fault zone (NIFZ), and the Hollywood fault zone as Holocene-active faults (Figure 1). The CGS map also identifies an active fault coincident with the West Beverly Hills Lineament (WBHL) that is roughly in line with, and potentially an extension of the northern Newport-Inglewood fault zone. An active fault is defined as a fault that has had movement in the past 11,700 years. The Santa Monica fault zone, the Newport-Inglewood fault zone, and the Hollywood fault zone have all been demonstrated in areas close to Century City to have had movement in the past 11,700 years and to be active faults.

**Metro Board Review**

Based on geologic and topographic evidence and fault maps existing at the time, the first proposed station location on Santa Monica Boulevard was centered on Avenue of the Stars and was originally expected to be outside of the Santa Monica fault zone. However, boreholes and other subsurface investigations conducted in 2010 revealed that the Santa Monica Fault Zone would impact this station.

On October 28, 2010 in the Metro Board meeting, Metro staff described the severe impact of the active Santa Monica fault zone on the proposed Santa Monica Boulevard Station at Avenue of the Stars. Metro staff was directed to fully investigate the nature and location of faults in the Century City area, and their potential impact on the proposed station location, as described below. In order to site a station farther away from the Santa Monica Fault Zone, Metro subsequently proposed an alternate eastward-shifted station location on Santa Monica Boulevard, centered on South Moreno Drive (Figure 2)**.**

**Century City Fault Investigation Report**

In 2011 Metro performed an extensive exploration program that included seven rotary-wash continuous core boreholes, 49 hollow stem auger continuous core boreholes, 192 cone-penetrometer tests (CPTs), five P-wave seismic reflection profiles, five S-wave seismic reflection profiles, and five down-hole suspension PS velocity measurements along seven transects. The transect locations are also shown on Figure 2. The transects consisted of linear series of subsurface explorations (boreholes and CPTs) oriented perpendicular to the

anticipated strike (trend) of the fault zones. In order to support fault interpretations between the explorations, continuous geophysical seismic survey lines were performed along the transects.[3]

Based on the data from the investigation, Metro concluded that faulting, clearly shown by the borehole, CPT, and geophysical data along Transect 2/2East, was present in Santa Monica Boulevard at the previously proposed eastern Santa Monica Boulevard station site. Faulting was also observed in Transects 1, 3, 4 and 7. Collectively, these data demonstrate that Santa Monica Boulevard from west of Century Park West to east of South Moreno Drive, encompassing both previously proposed Century City Santa Monica Boulevard station sites, lies within a complex zone of potentially active faulting associated with the Santa Monica fault zone, strands of which have been shown to be active several kilometers to the west of Century City in West Los Angeles.

**Complexity of Faulting in Century City Area**

The intersections of active fault systems, such as the intersection of the Santa Monica, Hollywood, and Newport-Inglewood fault systems encountered in the Century City-Beverly Hills area, are sites of severe structural complexity (Figure 3). These complex zones comprise numerous individual fault traces and generate complicated ground deformations that can include wide zones of over-thrusting, strike-slip displacement, tilting, and folding. In the absence of direct evidence that an individual fault trace is inactive within a complex area of known active faulting, the accepted standard is to assume that the fault trace is active. All three of the major fault systems that intersect in the Century City-Beverly Hills area – the Santa Monica, northern Newport-Inglewood, and Hollywood fault zones – have been demonstrated in areas close to Century City to be active.

In this regard, the new LCI trench data, although restricted to the area of the BHHS campus, provide new and valuable information that helps to clarify the locations and orientations of major faults in the Century City area. Specifically, Metro concurs with LCI's assessment that the major fault they discovered in their trench FT-5 is a continuation of the same fault observed in Metro subsurface and geophysical data farther to the west. This fault cuts through soil ~100,000years old, demonstrating fault activity after that date, but the age of most recent activity cannot be determined from the LCI trench data due to the loss of younger geological strata through erosion and urban development. Despite this uncertainty, LCI's discovery of the eastward extension of the southernmost Santa Monica fault strand provides useful information necessary to more clearly define the breadth and location of faulting associated with the Santa Monica fault system in the Century City-Beverly Hills area.

As shown in Figure 2, the available data demonstrate that the ENE-trending Santa Monica fault zone, which encompasses numerous individual strands, widens eastward towards its intersection with the NNW-trending northern Newport-Inglewood fault zone and the NNE-trending fault that connects the active Santa Monica and Hollywood fault systems. As noted above, this level of eastward-increasing structural complexity is to be expected in this area of major fault intersections. The eastward widening of the Santa Monica fault zone revealed by the new LCI trench data confirms that the Santa Monica fault is actually a wide zone of active and potentially active fault strands extending sub-parallel to Santa Monica Boulevard. This zone, the northern and southern limits of which are shown on Figure 2, includes numerous significant fault strands identified by Metro beneath Santa Monica Boulevard. Specifically, in addition to the

[3] Metro, Century City Area Fault Investigation Report, November 2011

well-documented structural and geomorphic manifestation of the ENE-trending Santa Monica fault zone along Santa Monica Boulevard in the vicinity of Avenue of the Stars and Century Park West, extensive borehole, CPT, and geophysical data along Metro's Transect 2/2East revealed several major faults that cut strata beneath Santa Monica Boulevard to the east of Century Park East, in a zone centered approximately on the intersection with South Moreno Drive.

The new LCI data showing that the ENE-trending, southernmost strand of the Santa Monica fault extends farther east than previously known indicates that the faults identified in Transect 2/2East, beneath Santa Monica Boulevard, lie within the eastward-widening zone of multiple Santa Monica fault strands, and are thus likely also Santa Monica fault strands. If the major ENE-trending fault documented by LCI in the trench FT-5 is not active, then active strands of the Santa Monica fault zone must lie to the north of the fault documented by LCI, closer to or through the eastern proposed Santa Monica station site (Century Park East and Avenue of the Stars).

In summary, the available data demonstrate that recently active strands of the Santa Monica fault zone extend farther east and south than previously observed. This demonstrates that the entire length of Santa Monica Boulevard from west of Century Park West to east of South Moreno Drive, encompassing both previously considered Century City Santa Monica Boulevard station sites, lies within a complex zone of potentially active faulting associated with the Santa Monica fault zone. Strands of the Santa Monica fault zone have been shown to be active several kilometers to the west in West Los Angeles. The new LCI trench data, in conjunction with Metro's data in the Century City area, re-emphasize and reinforce the risk associated with active faulting in this structurally complex area, as originally documented in earlier Metro reports.

**Conclusions**

No additional investigation has been performed by LCI in or around Santa Monica Boulevard. The LCI report concludes that there are no active faults on the northern BHHS campus, which encompasses a small portion of the Newport-Inglewood Fault Zone mapped by Metro. The letter from CGS concurs with that conclusion.

The LCI observations and investigations do not extend beyond 100 feet north of the northern portion of the Beverly Hills High School campus, and the LCI report and CGS letter do not address the presence of faulting at the previously considered station sites along Santa Monica Boulevard.

In the BHHS trench and boreholes, LCI identified a major fault south of Santa Monica Boulevard that is aligned with the southernmost strand of the Santa Monica fault zone fault south of Santa Monica Boulevard previously mapped by Metro farther to the west. LCI's discovery that this southernmost strand of the Santa Monica fault zone extends farther east and south than suggested on the basis of previously available data confirms that the intersection of the Santa Monica, northern Newport-Inglewood, and Hollywood fault systems in the Century City-Beverly Hills area is a zone of severe structural complexity with a large number of active and potentially active fault strands. The state of activity or inactivity of most of these fault strands cannot be determined with certainty due to the logistically complicated urbanized setting.

Significant faulting is present beneath and adjacent to Santa Monica Boulevard. The previously proposed Santa Monica Boulevard Station sites are located in an area of high structural complexity, which likely includes folding, secondary faulting, and off-fault, and distributed

deformation. The Santa Monica fault system has been shown to be active at a site several kilometers to the west of Century City, and since the Santa Monica fault zone extends northeastward as the Holocene-active Hollywood fault, it is active in Century City. Thus, at least some of the numerous strands identified in the various investigations described above must be active and capable of generating damaging earthquakes. Moreover, the presence of active fault strands at both Santa Monica Boulevard station locations cannot be disproven, due to local disturbances (utility lines, other historical excavations) and removal of Holocene-age sediments or soil horizons. In contrast, the Constellation station location is outside zones of active faulting, and Metro has made the decision to place the station at the site free from faulting. The new data do not support a change to Metro's conclusion that a station should not be located on Santa Monica Boulevard.

Attachments: Figure 1 – CGS Fault Activity Map

Figure 2 –Transect Location Map

Figure 3 – Zone of Complex Faulting

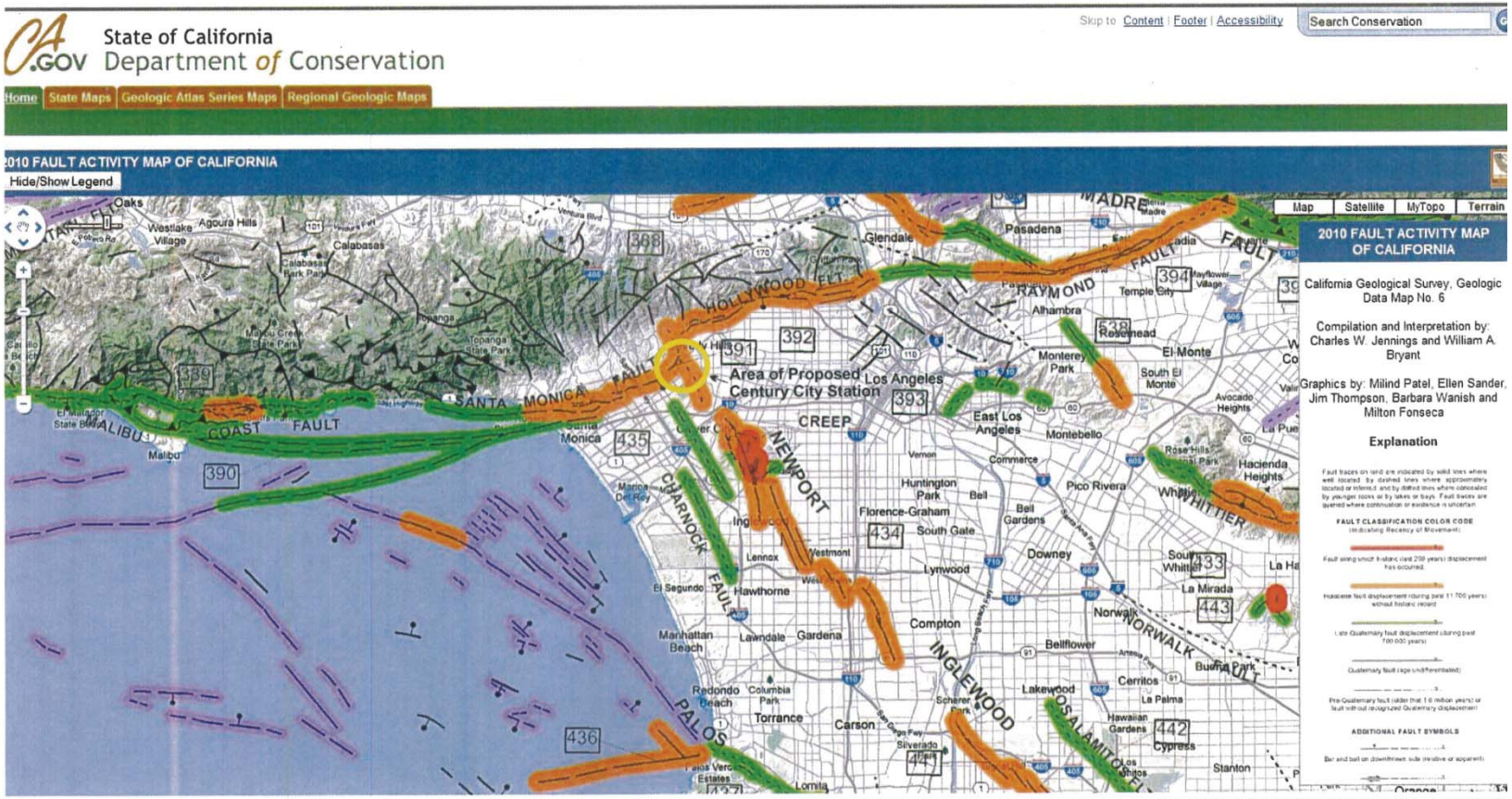
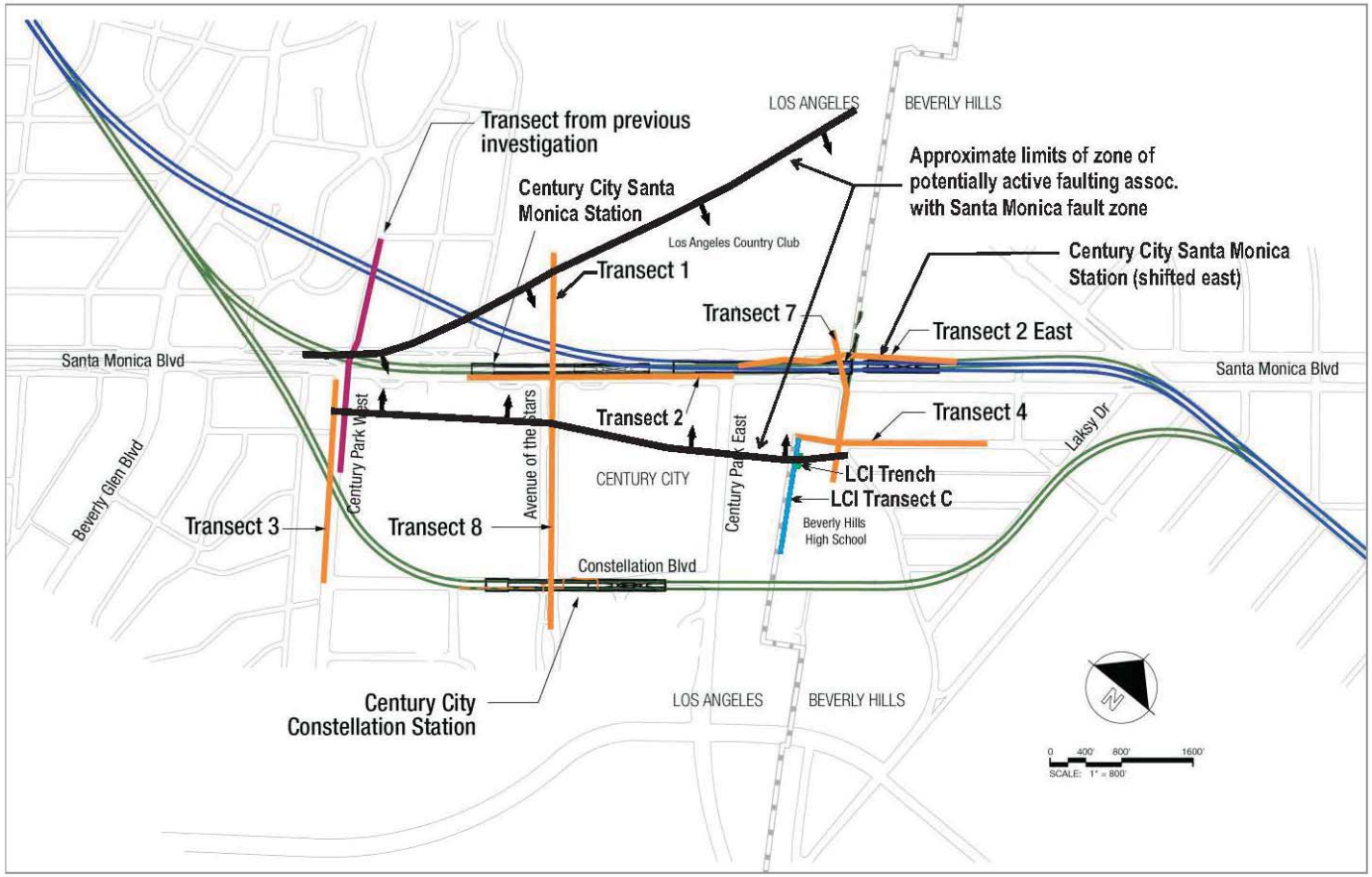
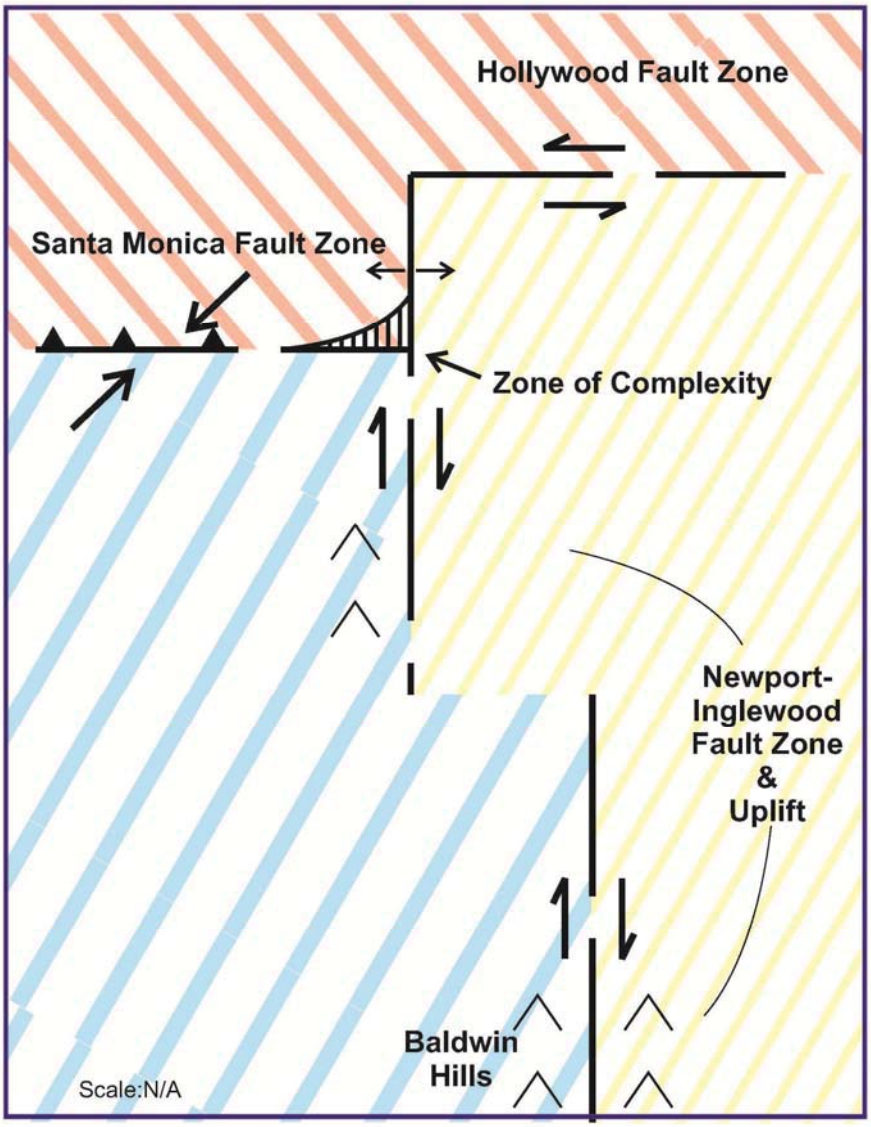



Figure 1
CGS Fault Activity Map




Study sites, proposed station options, and approximate limits of zone of potentially active faulting associated with the Santa Monica fault zone in the Century City area; strands of the northern Newport-Inglewood fault zone not shown. Note eastward-widening zone of structural complexity and potentially active faulting defined by the prominent topographic scarp on the north and the major fault identified by LCI and Metro on the south.

**Figure 2**
**Transect Location Map**




Schematic diagram showing the relationships between the three major fault systems, shown as single lines for simplicity, that intersect in the Century City area (Santa Monica fault, northern Newport-Inglewood fault, and the fault connecting the active Santa Monica and Hollywood fault systems). The Santa Monica fault, which has been shown to be active several kilometers to the west in West LA extends eastward to its intersection with the north-northwest trending northern NIFZ, in an eastward-widening zone of structural complexity comprising multiple potentially active strands (see Figure 2). In addition, the Santa Monica fault connects eastward to the Hollywood fault along a NNW- to N-S-trending fault that accommodates the different motions on the Santa Monica and Hollywood faults. Such zones of fault intersection are always structurally complex, comprising multiple potentially active fault strands as well as distributed deformation including folding, tilting, and minor faulting.

Figure 3
Zone of Complex Faulting